7th Low Emittance Rings Workshop
CERN, 15th January 2018

Comments on resistive measurement of NEG coated surface

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MY STARTING POINT (2004)

Idea:

Make a clean measurement of the value of the resistivity of a NEG compound.

Make the measurement at a frequency relevant with respect to the frequency spectrum of our storage ring bunch (14GHz)

Assumption:

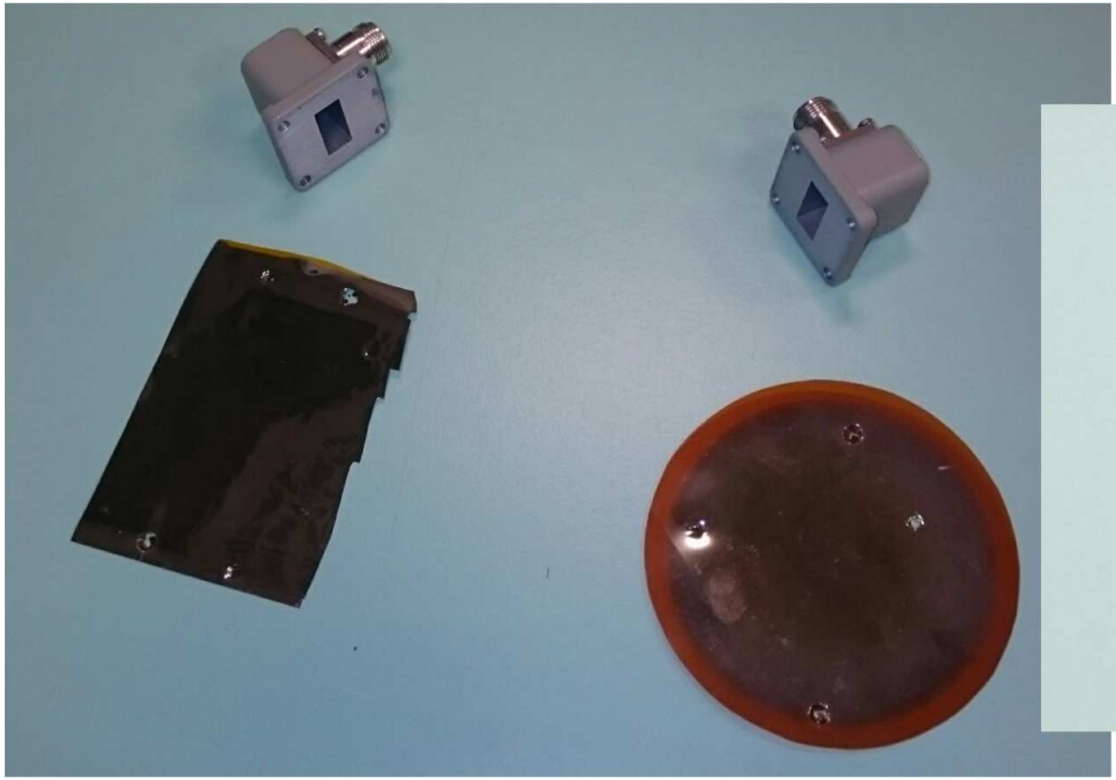
We assume that a NEG coating is an homogenous material which can be fully characterized by its resistivity

Measurement done in 2004 and crosschecked 2016

We coat a set of two thin kapton sheets with NEG

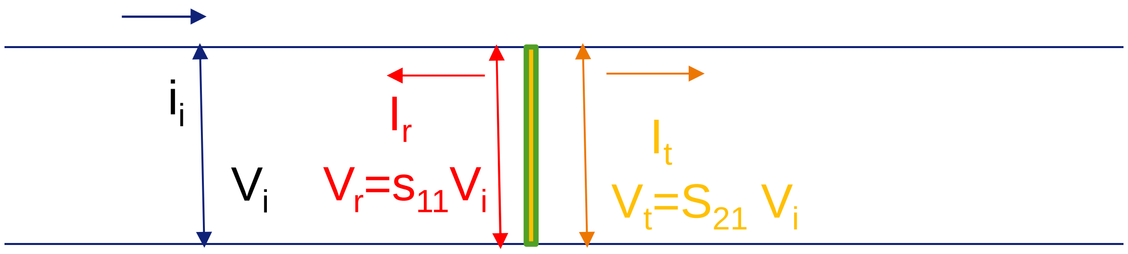
The NEG thickness is similar to the thickness of our vacuum chambers coating (th_1=.6μm and th_2=2 μm).

We insert the kapton sheets between the flanges of a pair of HF waveguide to coaxial transition and measure the transmission and reflection on the NEG coated kapton sheet using a microwave network analyzer at 14 GHz



RF instruments do not usually measure voltage , intensity , resistance

but instead measure power, power transmission, power reflection



However, the resistance of the NEG coated kapton sheet resistance Z_s is easy to derive from the s_{11} reflexion and s_{21} transmission coefficients:

$$Z_s / Z_0 = s_{21}/2$$

With $Z_0 = 330\Omega$

In the plane of the NEG coated kapton sheet we measured: s_{21} =.1 and .03 for the .6µm and 2µm coatings and s_{11} close to -1

=>

I_i+I_r close to 2 X I_i
V_t close to 2 (Z_s X I_i)
$V_t/V_s=s_{21}$
$I_i = V_i / Z_0$
So:

$$Z_s / Z_0 = s_{21}/2$$

NEG RESISTIVITY VALUE

for th_1 = .6µm we measure s21= .03 => Z_{s1} = 16.5 Ω

For th_2 = 2µm we measure s21= .1 => Z_{s2} = 5 Ω

The cross section of the wave guide is 22.5 X 10.5mm

The current is flowing between the large sides of the waveguide; so the surface resistances of the films are about 33 Ω /square for th_1 and 10 Ω /square for th_2
(the shape factor of a wave guide section is 22mmX9mm, about .4 square).

So the resistivity of the coating seems to be about 2.5 10^{-5} Ω.m
or for the conductivity: .4 10^5 S/m

To be perfectly correct, the derivation of the resistivity of the film from the film resistance should also take into account the pattern of the electric field intensity in the waveguide cross section: it is parallel to the small side of the waveguide, maximum in the middle, null on the side, with a cosine dependency…

TO SUM UP

It is a very simple set up

The measurement seems very clean:

No perturbation due to the roughness of the kapton/NEG interface.

The resolution is good (.1 and.03 transmission factor through the NEG coated foil sit almost ideally in the dynamic range of the network analyzer)

But eventually the measurement results are puzzling….

Very large discrepancy with others measurements made using different methods:

NEG (Ti V Zr):

$\sigma = 0.31 \cdot 10^6$ S/m **(**Sergio Calatroni, CERN: resistivity of TiVCr films)

$\sigma = 0.75 \times 10^6$ S/m (Eirini Koukovini-Platia, CERN)

Compared to:

$\sigma = 0.4 \times 10^5$ S/m (ESRF measurement)

FROM DISCUSSIONS WITH VARIOUS COLLEAGUES

- Roughness of the metallic surface where the deposit is made can be an important parameter:
  The kapton sheet surface is very smooth compared to extruded aluminum…

- Also depending of the coating method very large variation of the conductivity are possible (see tomorrow's presentation by Oleg B. Malyshev)

For instance concerning the coating method effect (Ti-Zr-Hf-V NEG coating):

From $\sigma = 1.4\times10^4$ S/m for a so called columnar NEG coating

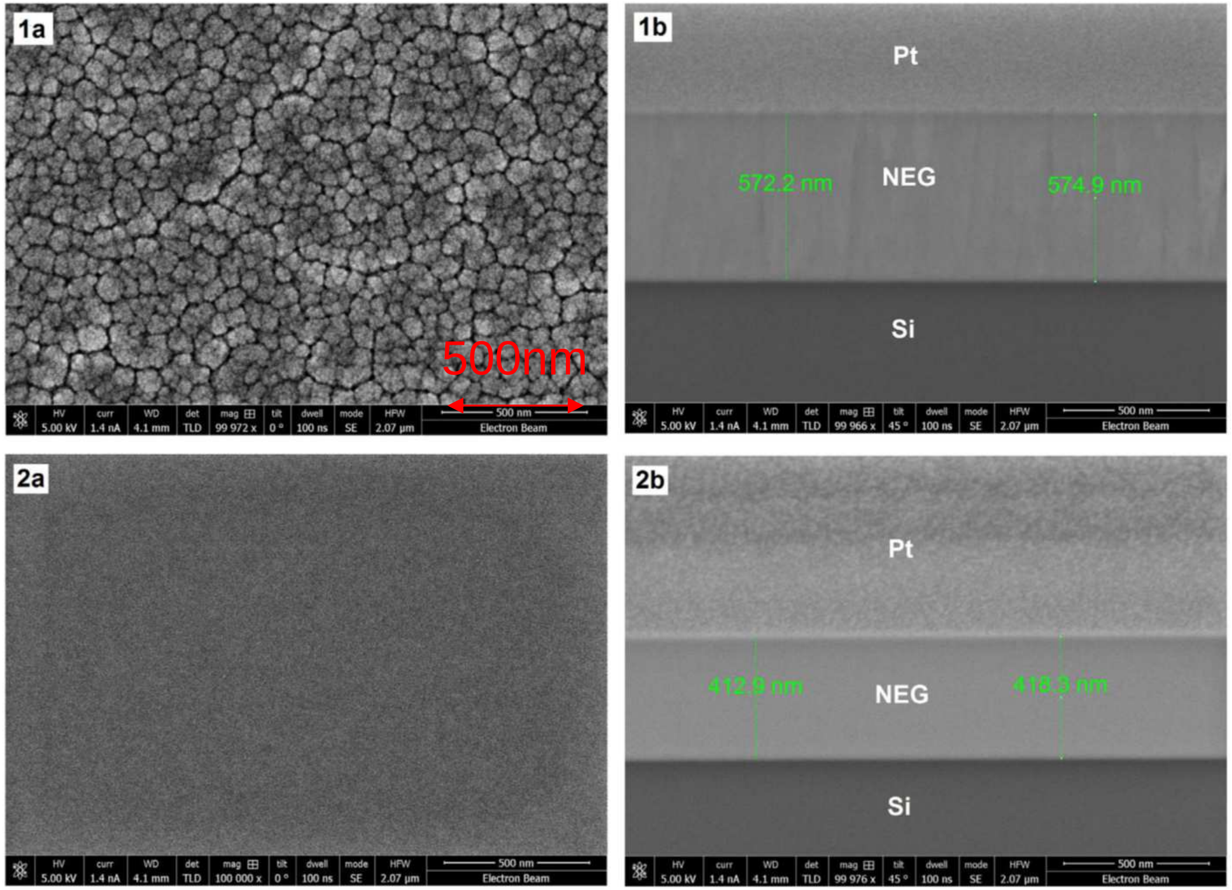
to $\sigma = 8\times10^5$ S/m for a so called dense NEG coating

From : "RF surface resistance study of non-evaporable getter coatings"

Oleg B. **Malyshev**, Lewis Gurran, Philippe Goudket, Kiril Marinov, Stuart Wilde, Reza Valizadeh, Graeme Burt

In Nuclear Instruments and Methods in Physics Research A 844 (2017) 99–107

COLUMNAR VERSUS DENSE NEG COATING



The high resolution (a) planar and (b) FIB prepared X-section SEM images of columnar (1a and 1b) and dense (2a and 2b) NEG films

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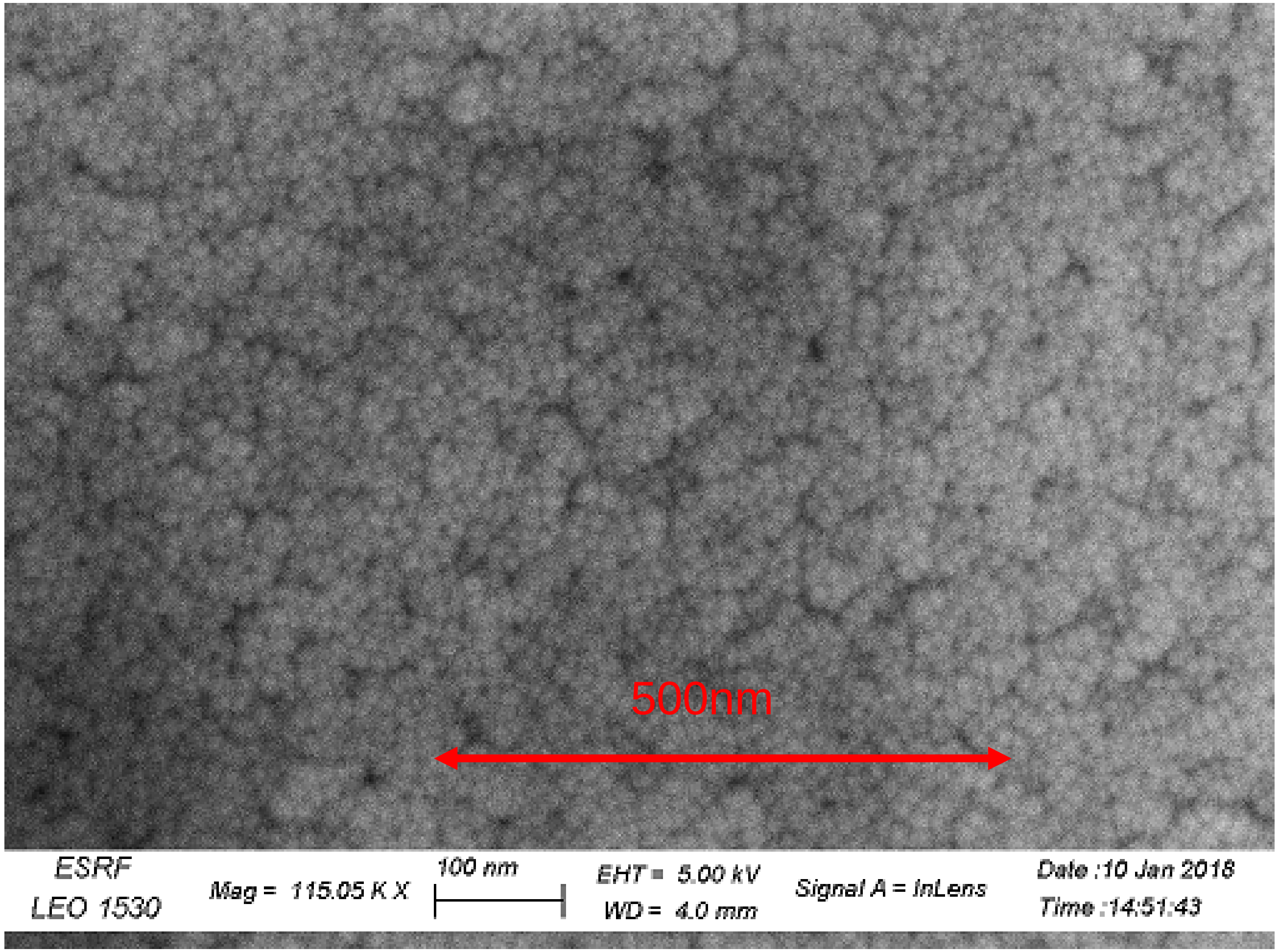
ESRF COATING



COLUMNAR PATTERN ALSO BUT WITH A SMALLER STRUCTURE SIZE

IMAGE DONE BY IRINA SNIGIREVA (ESRF)

CONCLUSION

Question: is there such a thing as a NEG conductivity value?

TWO POSSIBLE DIRECTIONS:

- Get data to predict how your own NEG coated vacuum chamber will affect the impedance of your accelerator

=> perform RF measurements on something as close as possible to your real vacuum chamber and obtain some loss factor figure over the relevant frequency range for your bunch shape

- Start a full research program dealing with all the aspects of the issue: electrochemistry, electromagnetism in weird microstructures ...


Thank you for your attention